# Technology Development for Planetary Protection

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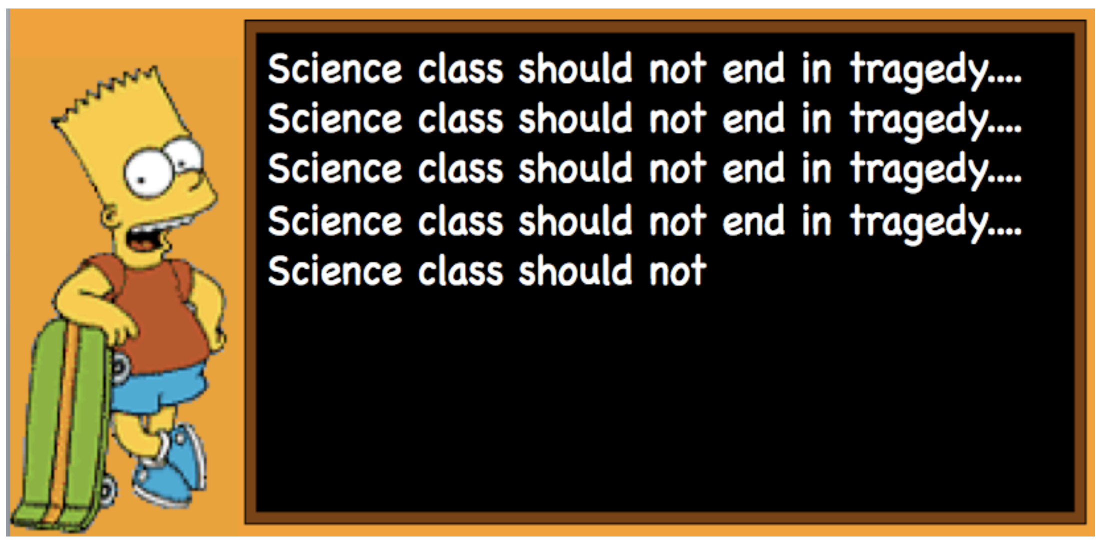
# Planetary Protection Policy



- Preserve planetary conditions for future biological and organic constituent exploration
  - *avoid forward contamination; preserve our investment in scientific exploration*
- Protect the Earth and its biosphere from potential extraterrestrial sources of contamination
  - *avoid backward contamination; provide for safe solar-system exploration*

COSPAR
COMMITTEE ON SPACE RESEARCH

**Complies with Article IX of the 1967 Outer Space Treaty**



# Planetary Protection Trade-Offs

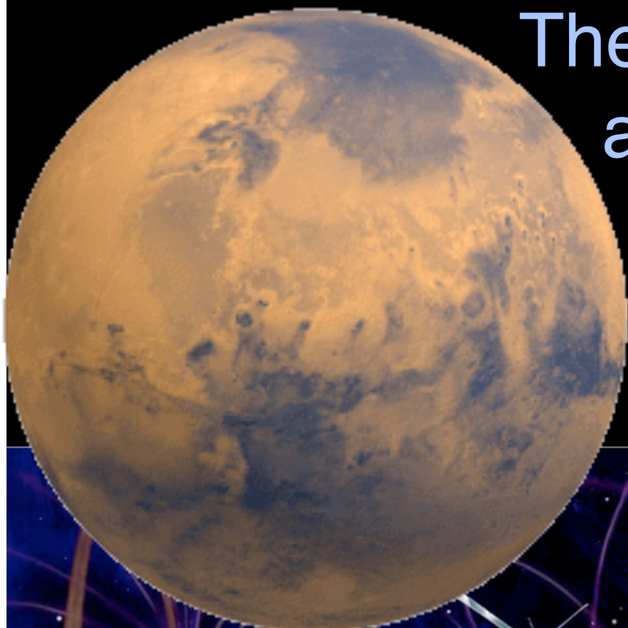


- Backward contamination involves a careful analysis of the potential for extraterrestrial life to be returned to Earth within a sample
  - Requires a conservative approach to executing sample return missions, despite the fact that extraterrestrial life cannot be proven to exist

- The difficulties of protecting the entire populace of the Earth from a biological unknown must be balanced against
  - The benefit of learning about extraterrestrial worlds
  - The benefit of learning about possible (or not?) extraterrestrial life

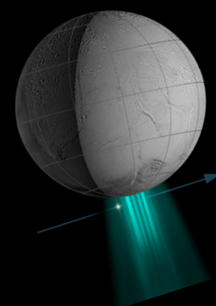
- Forward contamination of other worlds is governed by the presence of extraterrestrial Earth-like environments
  - There is no question that life exists here
  - Earth microbes are proving to be much more robust survivors than once was believed
  - Increasingly, there is evidence that Earth-like environments on other planets also exist

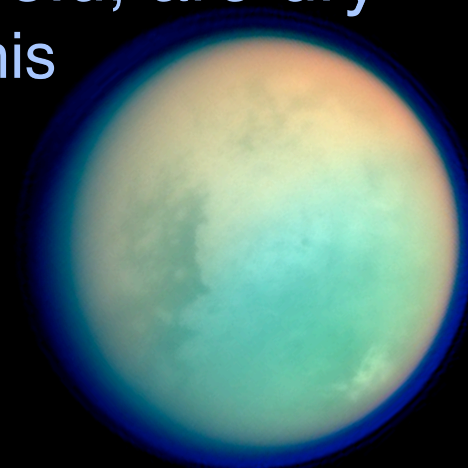
# Planetary Environments are Diverse

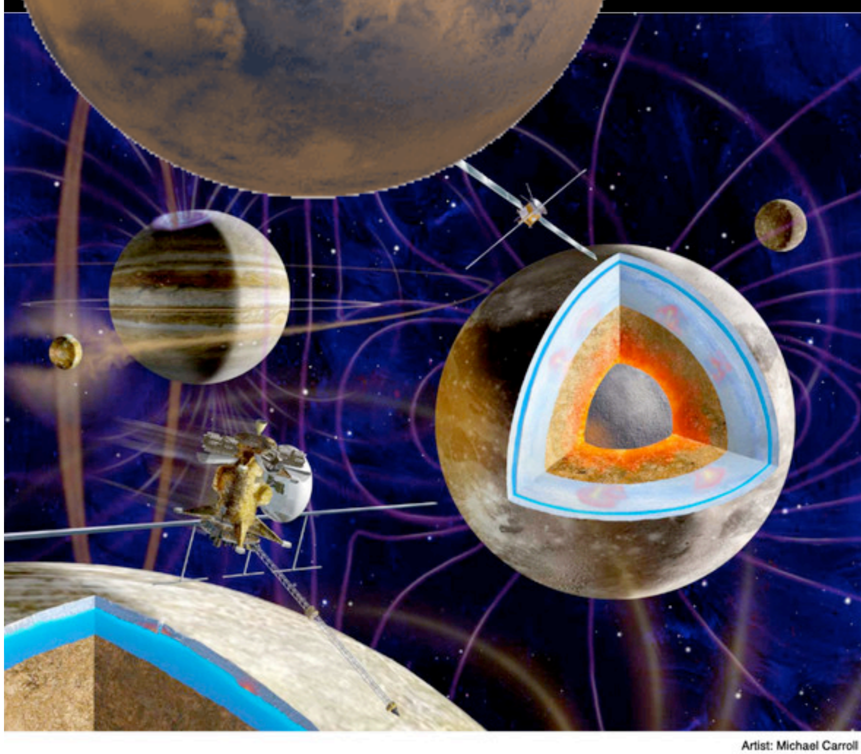


The unaltered surfaces of most planets are cold, and by being cold, are dry

- spacecraft can change this







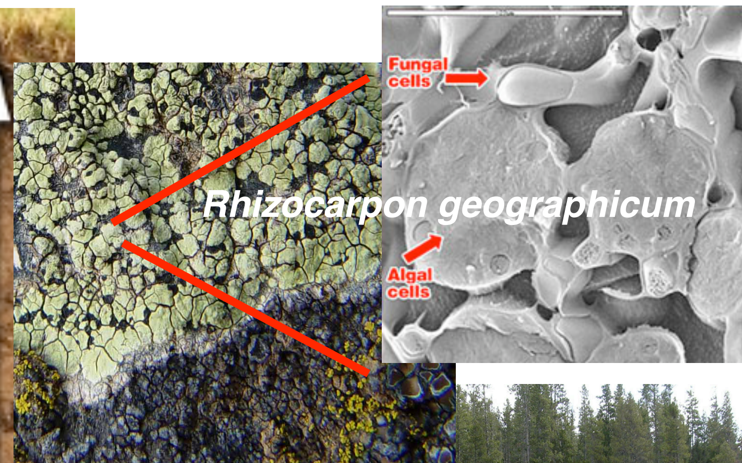

Interior environments may be more similar to Earth:

- possible subsurface oceans, both hot and cold
- subsurface rock, similar (?) to inhabited Earth rocks

# Earth Organisms are Diverse

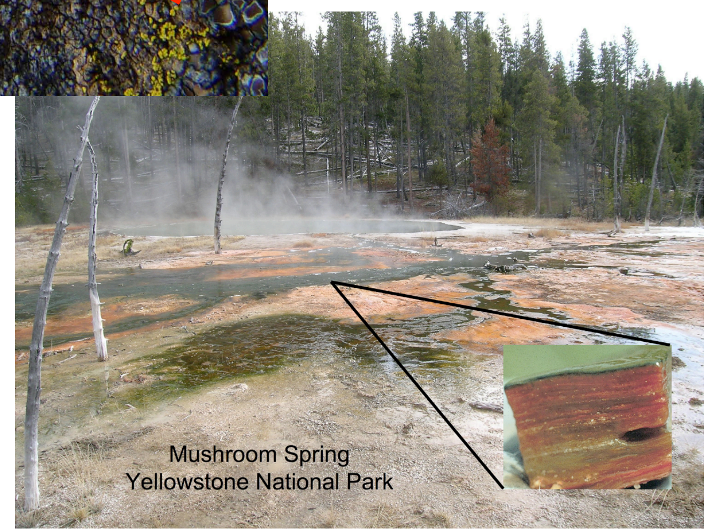


Most Earth organisms couldn't survive anywhere else in the solar system...


**Lichen survives space exposure**

But some are found in 'extreme' environments that resemble more closely locations on other planets.



# Biological Diversity on Spacecraft



Spacecraft assembly cleanrooms impose selective pressures on microbial inhabitants: oligotrophic (few particulates), harsh chemistry (cleaned with bleach), low microbial influx (ideally...)


Sampling of microbial populations on spacecraft is important to understand the diversity of hitchhiker organisms: numbers as well as complexity.

Community-level analysis has not been attempted, but will be critical to assess probability of growth.

# Planetary Protection Technologies

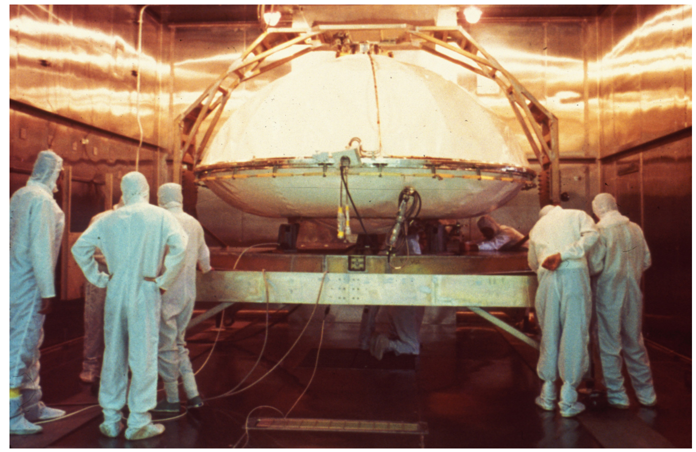


## Prelaunch/Operations Technologies

- Assays for rapid assessment of cleanliness (cultivable, non-cultivable, molecular)
- $H_2O_2$ and/or radiation sterilization of assembled subsystem
- Development of Mars orbital debris analysis code
- Aseptic assembly systems
- Particle transport models
- Cleaning to sterility

## Launched Hardware

Viking baked the whole lander...



- *In situ* sterilization systems
- Container sealing systems
- Earth targeting improvements
- Meteoroid protection on spacecraft
- Earth entry vehicle for assured containment
- Lightweight biobarriers for forward contamination prevention
- Mechanism or series of mechanisms for “break-the-chain” of contact

## Sample Handling Systems

- Multi-directional containment systems for sample handling
- Systems for analysis of contained samples (Sample Receiving Facility)

## Research Required to Inform the Development of Technologies

- Fundamental biology of survivability (microbial characterization in HW environments)
- Advanced spacecraft designs allowing sterilization, aseptic assembly, late RPS installation
- Materials screening to enable system/subsystem sterilization

# Planetary Protection Support Structure



- ROSES Planetary Protection Research (PPR) funds basic research on:
  - The capabilities of Earth life to survive in other planetary environments
  - The adaptation of existing technologies (microbial reduction, enumeration, etc.) for use in spacecraft assembly environments
  - Modeling of planetary environments (e.g., transport mechanisms) to support assessing level of forward contamination concern
- Flight Projects/Programs fund development of late-TRL technologies:
  - Demonstrate technologies relevant to that mission (e.g., biobarriers)
  - Evaluate spacecraft materials and components for compatibility with approved treatment modalities
  - Modeling efforts to demonstrate compliance with planetary protection requirements
- Nobody funds:
  - Progression of early TRL technologies, from a multi-mission standpoint, to a level such that a single mission could continue development

# Planetary Protection Funding

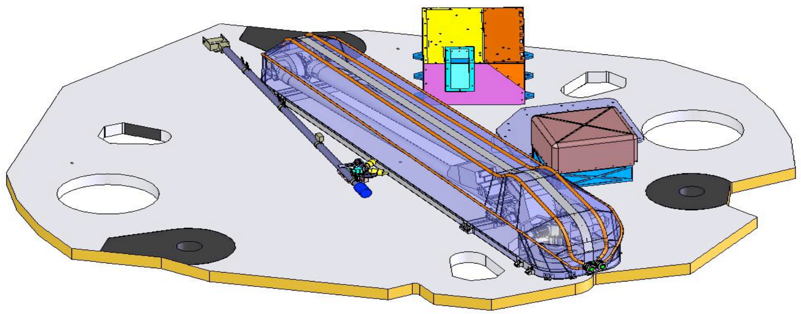


- ROSES Planetary Protection Research (PPR) funding:
  - Normally makes new selections in the range of $3-500K
  - Due to funding cuts, this year the funds available for new PPR starts is <100K
  - Continuing support for microbial detection, materials compatibility, and modeling research activities
  - The PPO budget at HQ also funds some coordination activities with ESA, e.g., validation of microbial reduction technologies
  - SBIRs and other funding vehicles provide a small supplement
- Mars Planetary Protection Technology Program at JPL:
  - Previously funded a variety of microbial detection, reduction, modeling, and materials compatibility development efforts
  - Currently, nearly all funding is directed towards microbial detection using molecular biology methods, in response to SSB recommendations
- Other missions are making an effort:
  - ASRG has recently been in communication on how to accommodate planetary protection requirements on a fully sterilized spacecraft: Unfortunately, there's not a lot of useful information available...

# Recent Successes



- ESA-NASA coordination effort is bearing fruit:
  - Jan. 23 review of work to extend the Dry Heat Microbial Reduction specifications to higher temperatures: very successful
  - Ongoing efforts to approve technologies evaluated by NASA/JPL and ESA – ESA resources are completing work that NASA/JPL started
  - Joint funding for work to provide consistent protocols for approving new technologies, coordinate acceptance of planetary protection assays, etc.
- Mars Program:
  - MSL embedded bioburden assessments allow the mission to meet total bioburden requirements
  - Biobarrier technologies worked perfectly on Phoenix




Don’t spill it!
Campbell's
Primordial
SOUP

# Planetary Protection Requirements



- Assignment of categories for each specific mission/body is to “take into account current scientific knowledge” via recommendations from scientific advisory groups.
- Categorization depends on the nature of the mission and on the target planet
- Examples of specific constraints include:
  - Limitations on spacecraft operating procedures
  - Inventory of spacecraft hardware and materials
  - Documentation of spacecraft trajectories and material archiving
  - Reduction of spacecraft biological contamination
  - Restrictions on the handling of returned samples
- Probabilistic requirements allow derivation of numerical limits on microbial contamination pre-launch

# Planetary Protection Mission Categories



| PLANET PRIORITIES | | MISSION TYPE | MISSION CATEGORY |
|---|---|---|---|
| A | Not of direct interest for understanding the process of chemical evolution. No protection of such planets is warranted. | Any | I |
| B | Of significant interest relative to the process of chemical evolution, but only a remote chance that contamination by spacecraft could jeopardize future exploration. Documentation is required. | Any | II |
| C | Of significant interest relative to the process of chemical evolution and/or the origin of life or for which scientific opinion provides a significant chance of contamination which could jeopardize a future biological experiment. Substantial documentation and mitigation is required. | Flyby, Orbiter | III |
| | | Lander, Probe | IV |
| All | Any Solar System Body | Earth-Return *"restricted" or "unrestricted"* | V |